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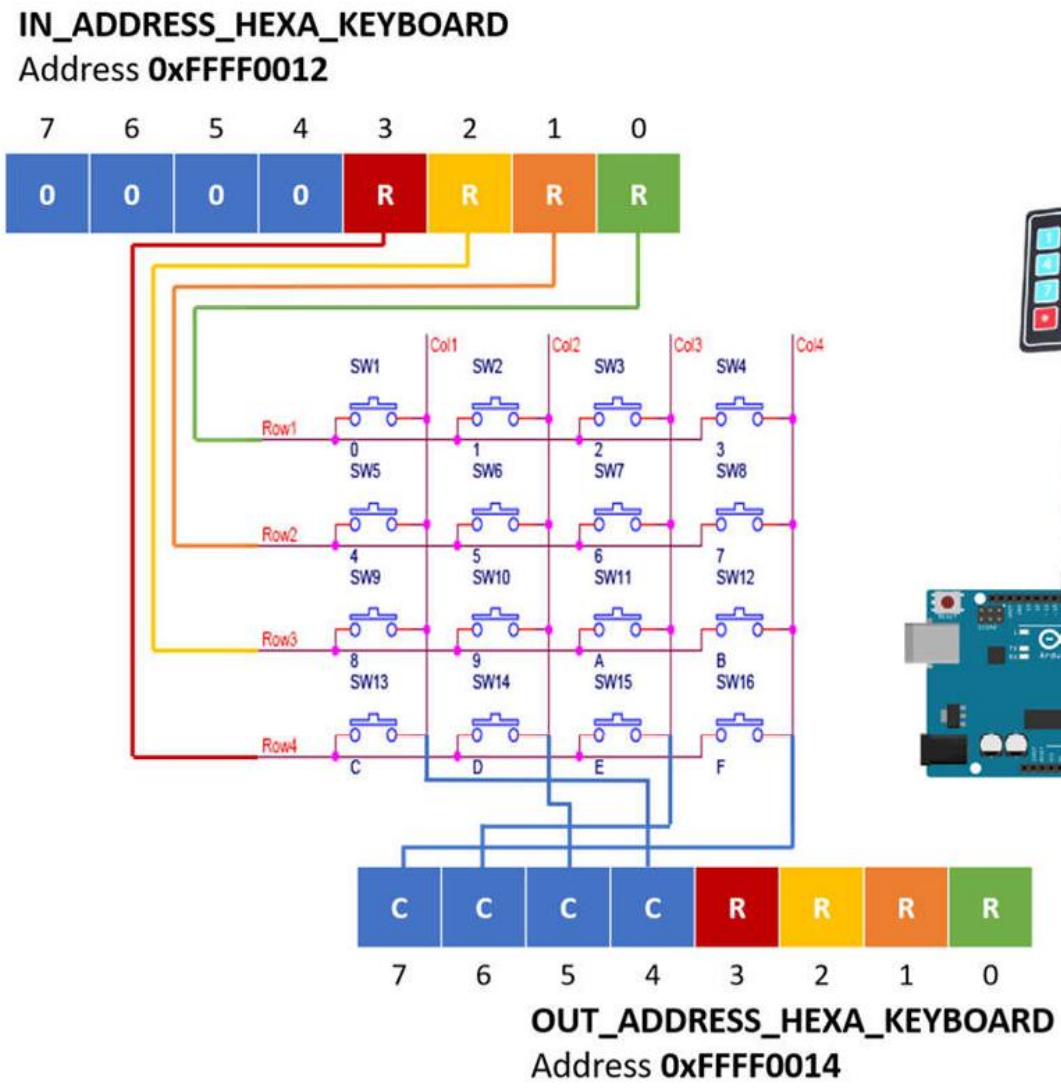
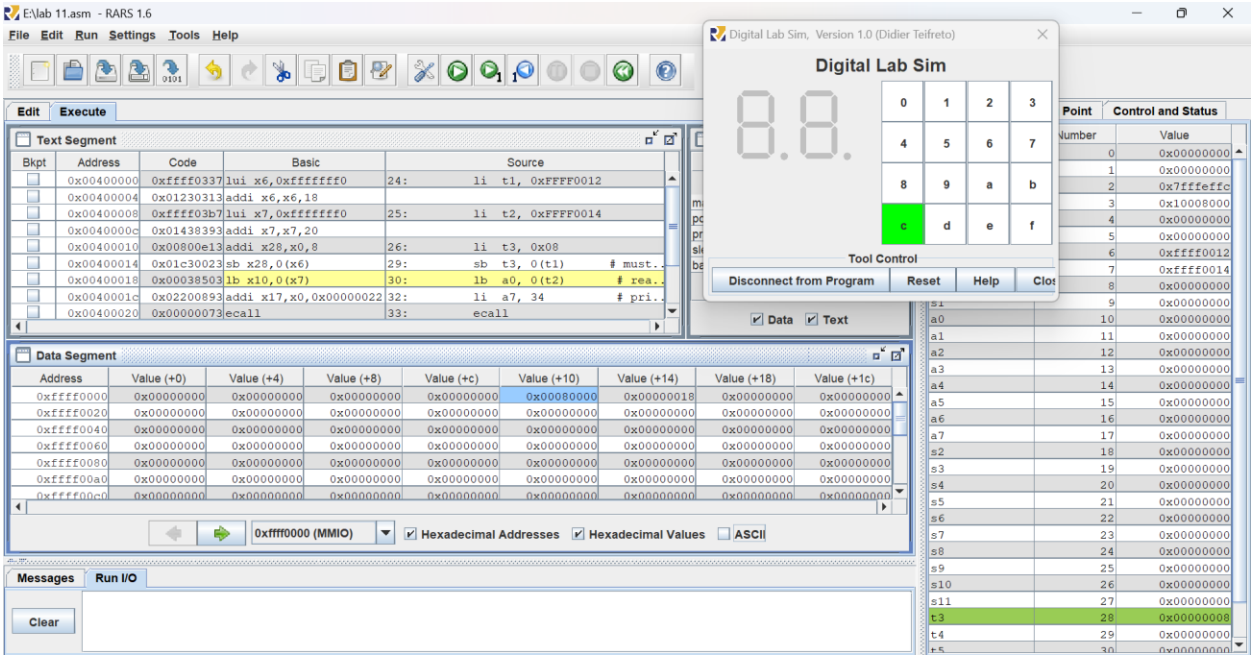
Lab 11

Assignment 1: Create a new project, type in, and build the program of Home Assignment 1. Run the program step by step to understand each line of the source code. Upgrade the source code so that it could detect all 16 key buttons, from 0 to F.

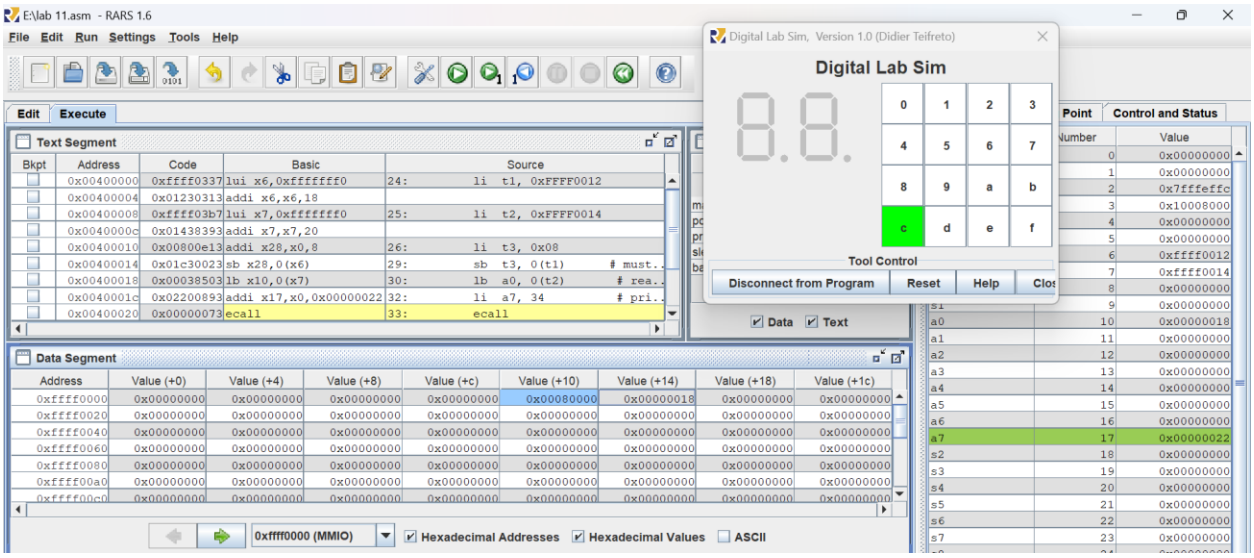


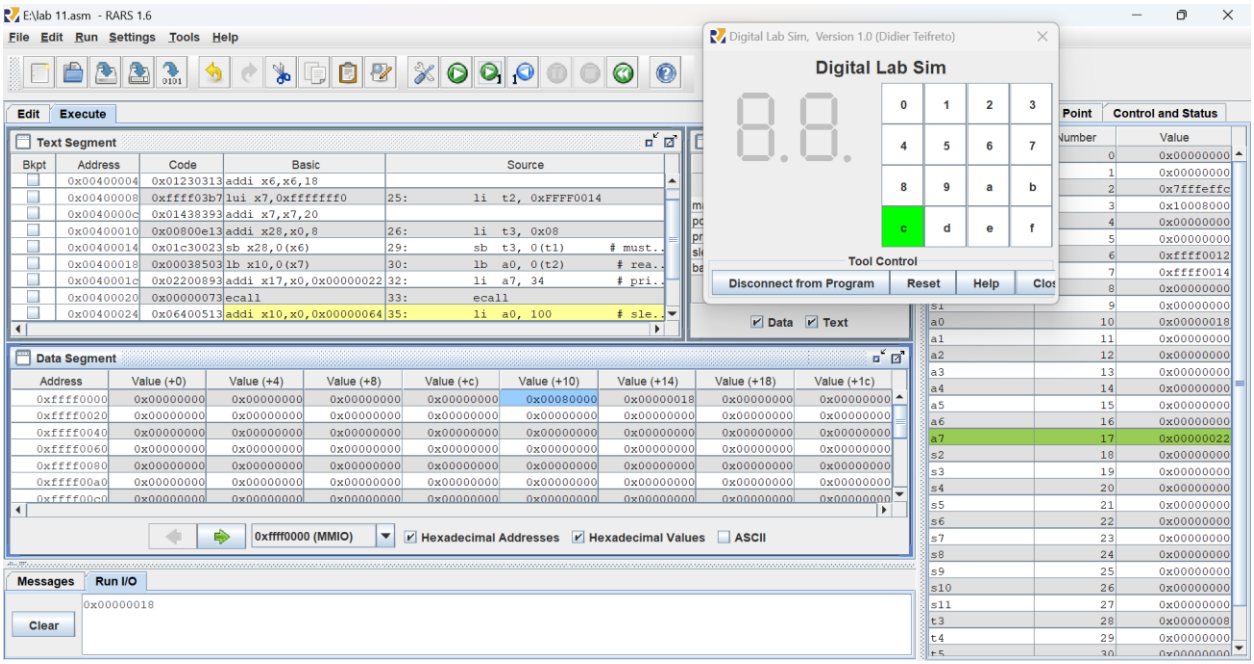
Run the program step by step:

Assigning value of row4 for the address 0xFFFF0012 which is 00001000 in binary or 0x8 in hexadecimal.

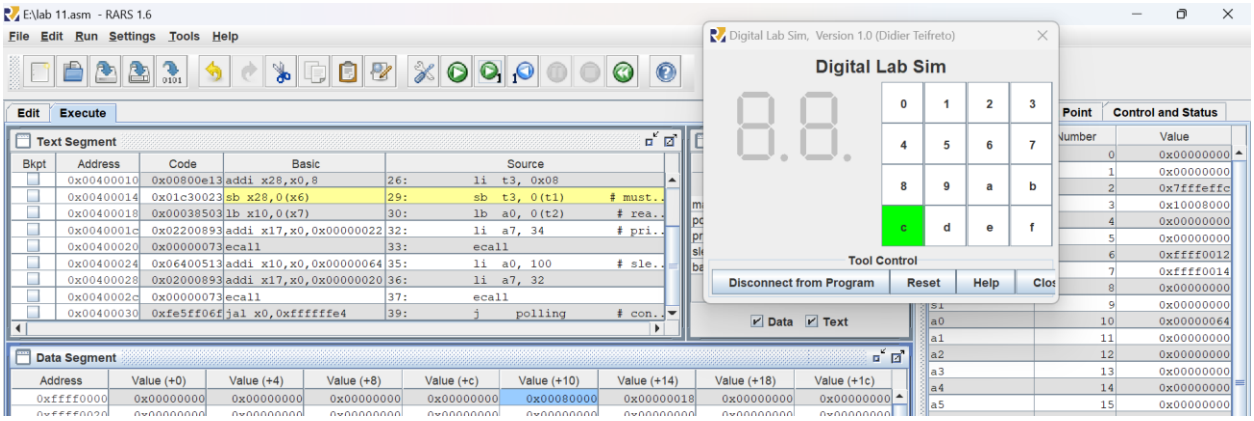


At the present, the address 0xFFFF0014 stores value of button key which is pressed. We load this value to the register t2 and print it to console

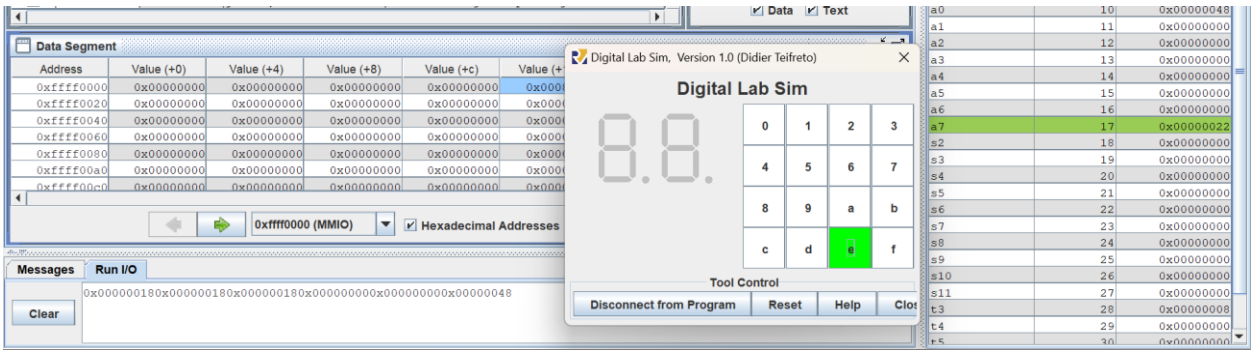




After printing the key number to console , the program sleeps in 100 ms. Then, it does the loop with the instruction “j polling” and executes above process again.



The value printing to console will have not changed until you press other button in set {d, e, f} or do not press any button (the value will be 0).



The updated source code is as below:

Edit Execute

lab 11.asm

```
1  # -------------------------------------------------------
2  #           col 0x1    col 0x2    col 0x4     col 0x8
3  #  row 0x1      0          1          2           3
4  #             0x11       0x21       0x41        0x81
5  #  row 0x2      4          5          6           7
6  #             0x12       0x22       0x42        0x82
7  #  row 0x4      8          9          a           b
8  #             0x14       0x24       0x44        0x84
9  #  row 0x8      c          d          e           f
10 #             0x18       0x28       0x48        0x88
11 # -------------------------------------------------------
12 # Command row number of hexadecimal keyboard (bit 0 to 3)
13 # Eg. assign 0x1, to get key button 0,1,2,3
14 #     assign 0x2, to get key button 4,5,6,7
15 # NOTE must reassign value for this address before reading,
16 # eventhough you only want to scan 1 row
17 .eqv IN_ADDRESS_HEXA_KEYBOARD       0xFFFF0012
18 # Receive row and column of the key pressed, 0 if not key pressed
19 # Eg. equal 0x11, means that key button 0 pressed.
20 # Eg. equal 0x28, means that key button D pressed.
21 .eqv OUT_ADDRESS_HEXA_KEYBOARD      0xFFFF0014
22 .text
```

Line: 53 Column: 7 ☑ Show Line Numbers

Edit Execute

lab 11.asm*

```
19 # Eg. equal 0x11, means that key button 0 pressed.
20 # Eg. equal 0x28, means that key button D pressed.
21 .eqv OUT_ADDRESS_HEXA_KEYBOARD      0xFFFF0014
22 .text
23 main:
24         li   t1, IN_ADDRESS_HEXA_KEYBOARD
25         li   t2, OUT_ADDRESS_HEXA_KEYBOARD
26 # check row 4 with key C, D, E, F
27 polling:
28         li   t3, 0x01
29         sb   t3, 0(t1)       # must reassign expected row
30         lb   a0, 0(t2)        # read scan code of key button
31         bnez a0, print
32
33         li t3, 0x02
34         sb t3, 0(t1)
35         lb a0, 0(t2)
36         bnez a0, print
37
38         li t3, 0x04
39         sb t3, 0(t1)
40         lb a0, 0(t2)
```

Line: 25 Column: 36 ☑ Show Line Numbers

Edit Execute

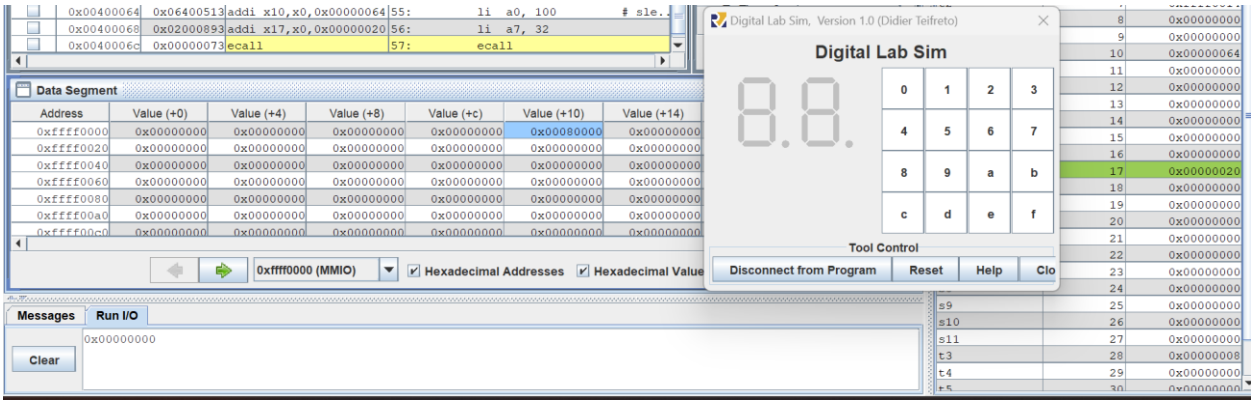
lab 11.asm

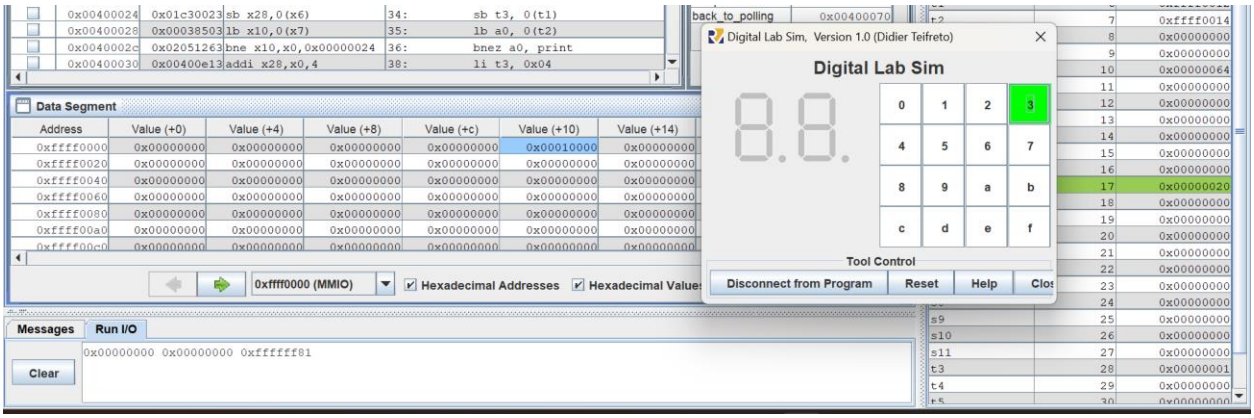
```
39          sb t3, 0(t1)
40          lb a0, 0(t2)
41          bnez a0, print
42
43          li t3, 0x08
44          sb t3, 0(t1)
45          lb a0, 0(t2)
46          bnez a0, print
47  print:
48          li  a7, 34          # print integer (hexa)
49          ecall
50
51          li a7, 11
52          li a0, 32
53          ecall
54  sleep:
55          li  a0, 100         # sleep 100ms
56          li  a7, 32
57          ecall
58  back_to_polling:
59          j     polling       # continue polling
```

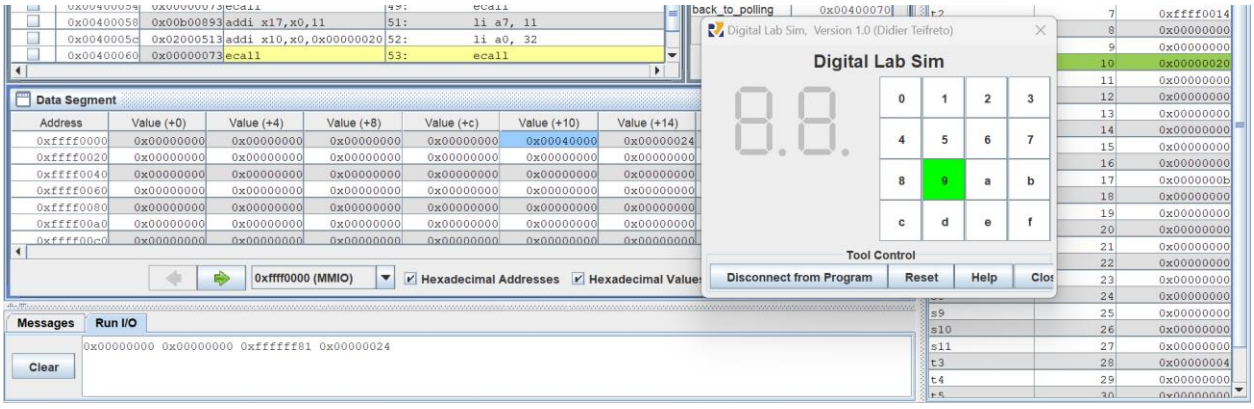
Line: 53 Column: 7 Show Line Numbers

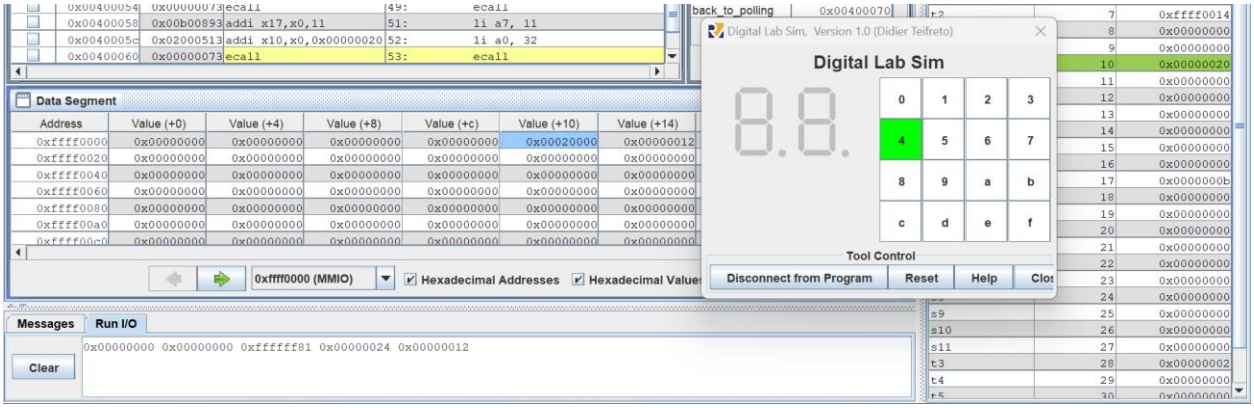
The new program will consider each row to detect which button key is pressed. If we have the answer, print the number key. If there are not any buttons are pressed, print 0x00000000

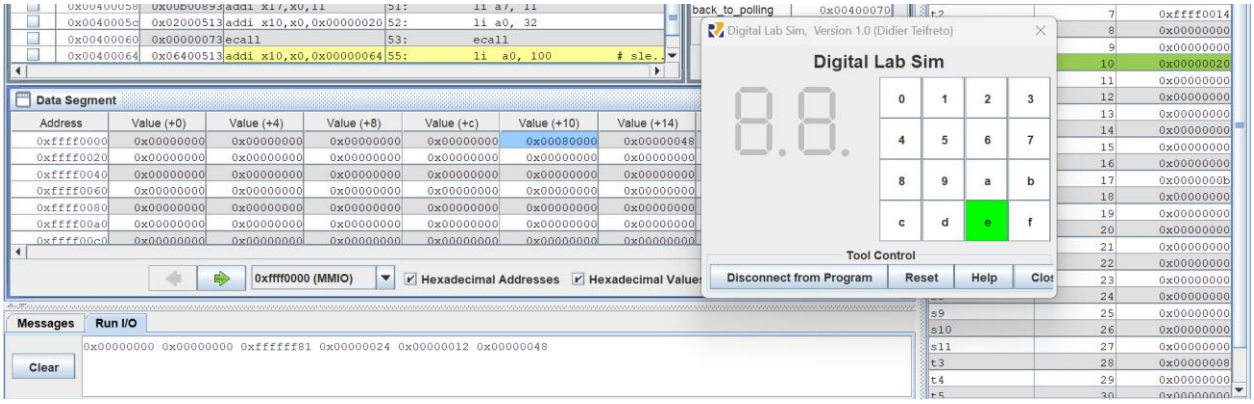
Example:





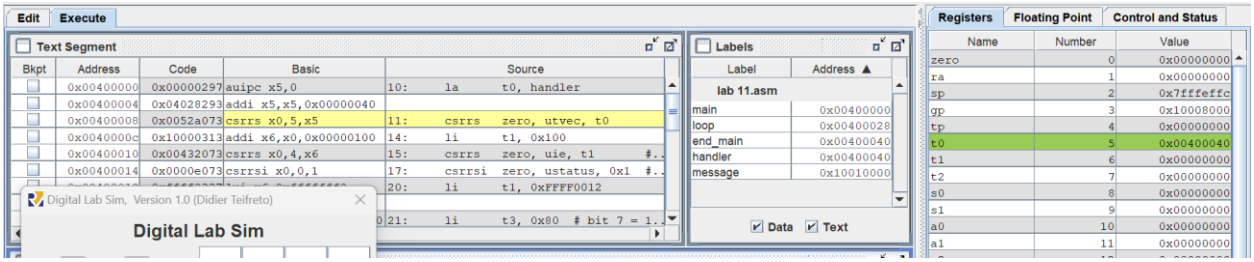




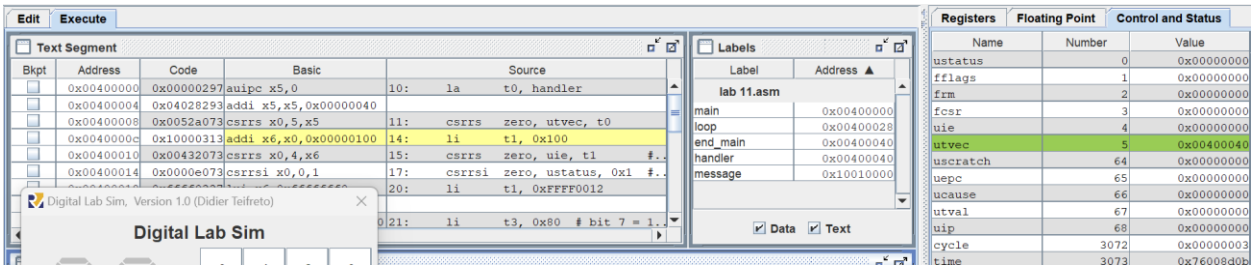


Assignment 2: Create a new project, type in, and build the program of Home Assignment 2. Run the program step by step to understand each line of the source code.

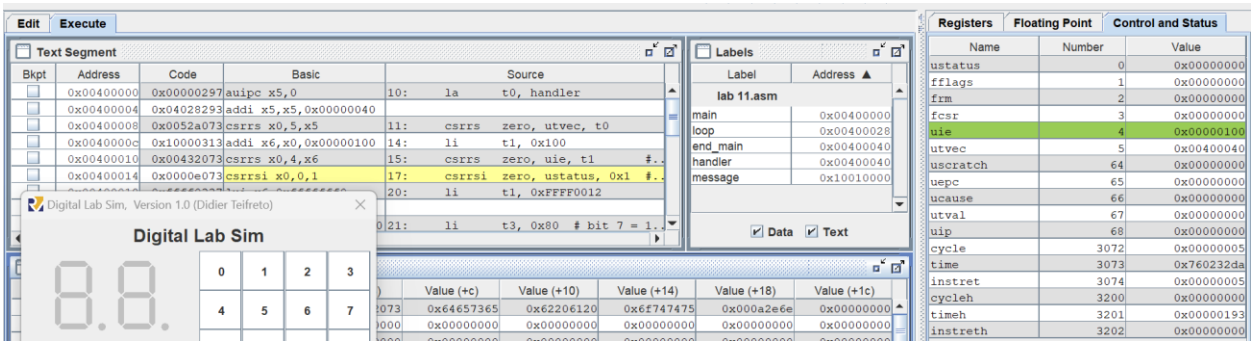
Load address of handler to register t0



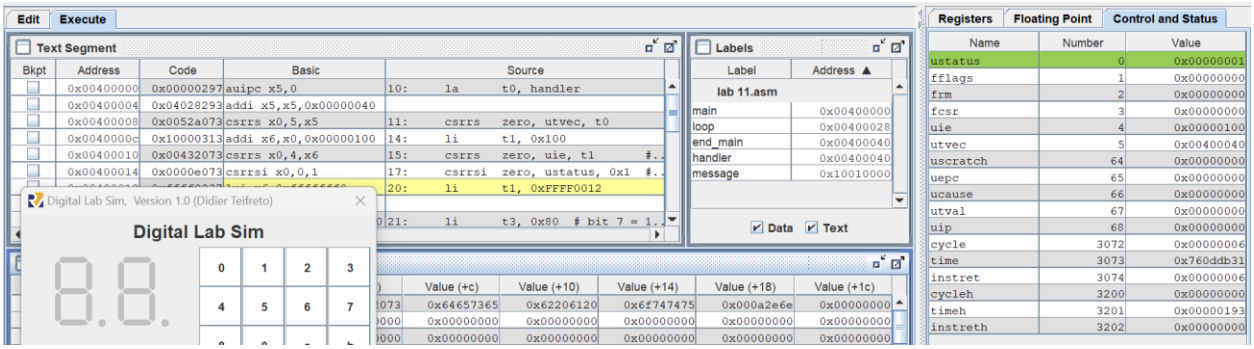
Then, assign this address to utvec



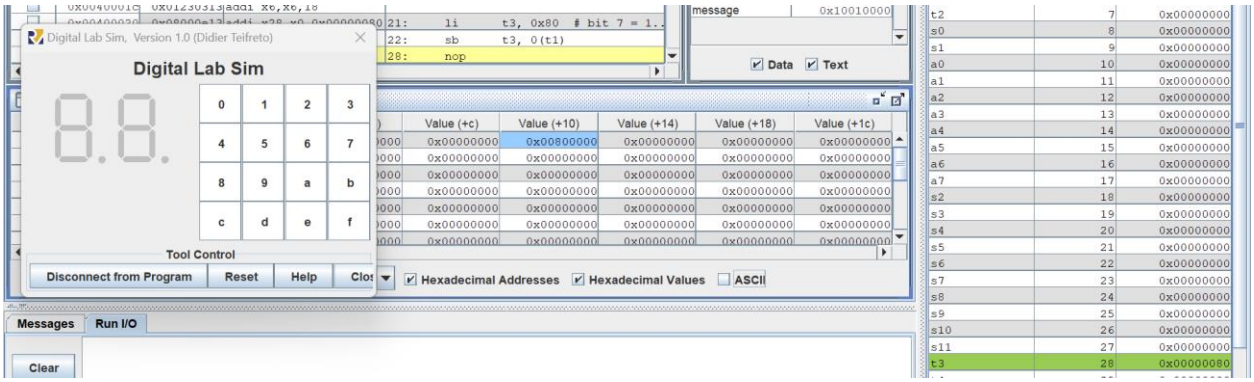
Set the UEIE bit in UIE register



Set the UIE bit in USTATUS register in order to enable interrupts

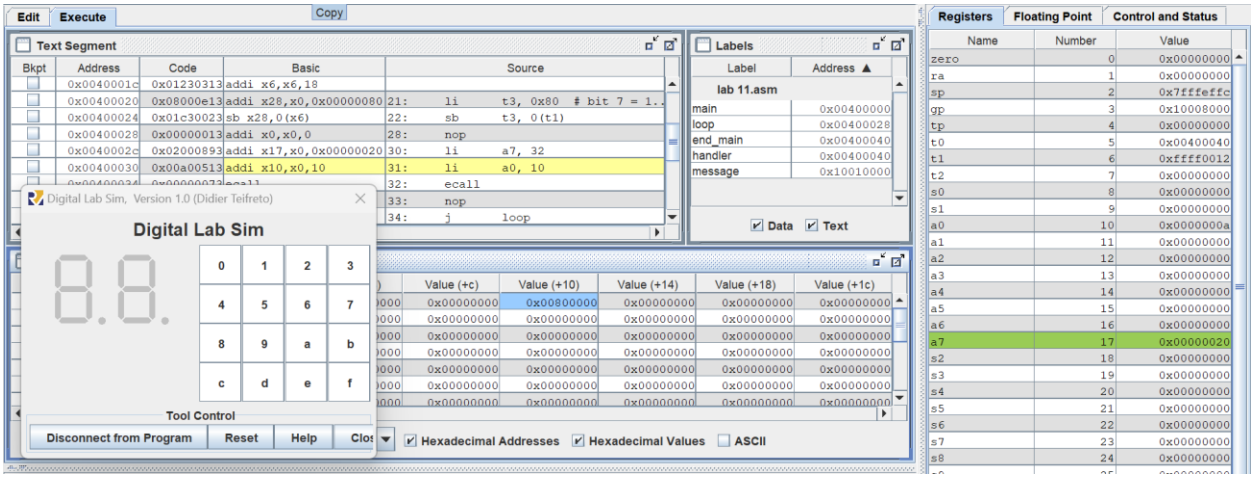


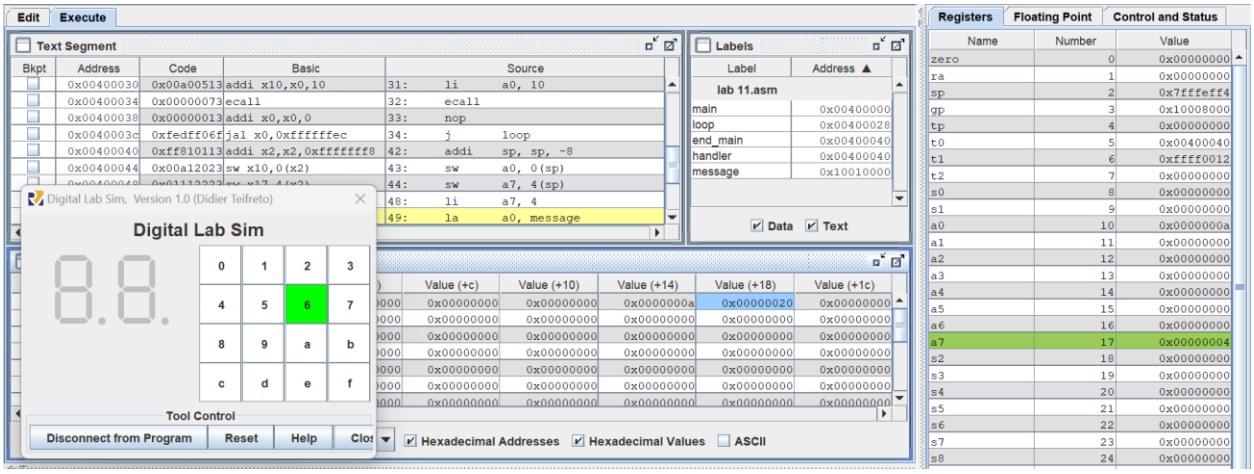
Enable the interrupt of keypad of Digital Lab Sim, set bit 7 to value of 1

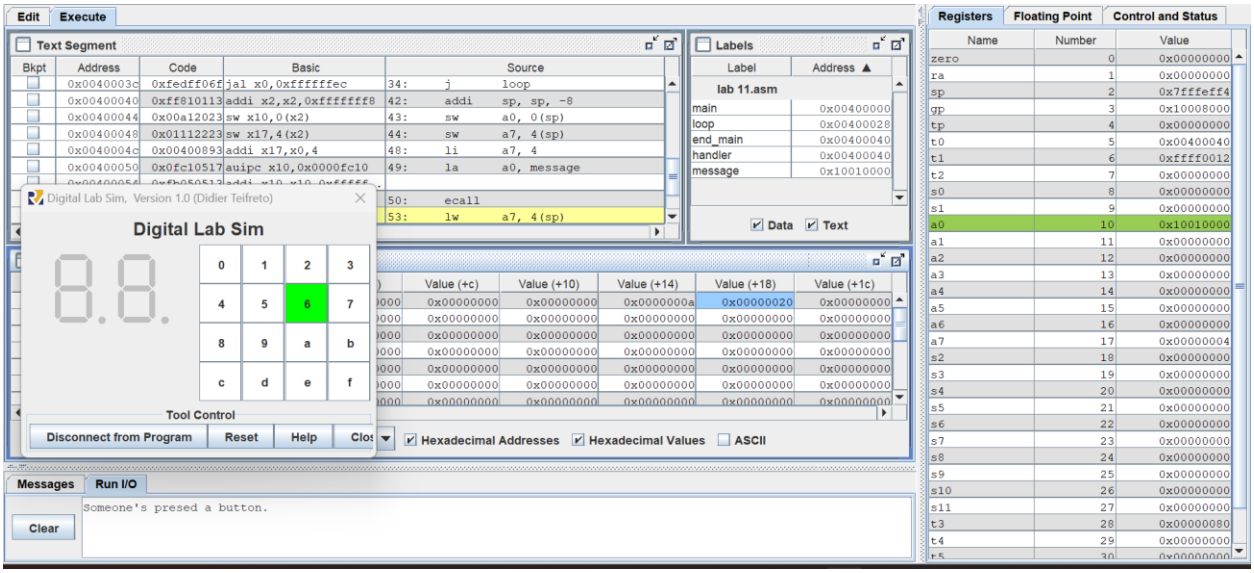


At this time, we have already finished all of preparation and just wait for interrupts occurring.

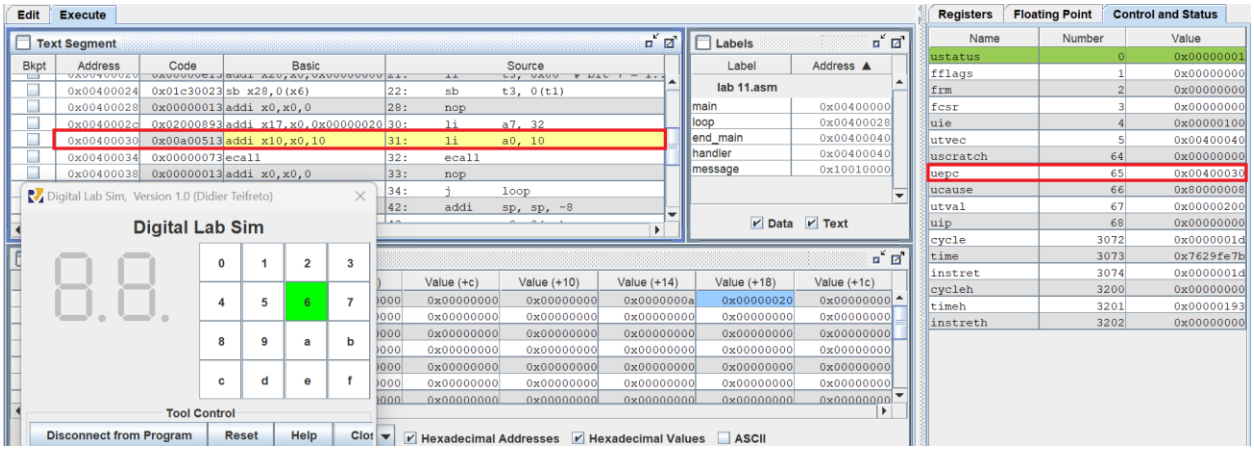
The program will have executed this loop until there exists interrupts. In this case, interrupt is pressing an button. Then, the main program will stops temporarily to handle interrupts. The context in main program is stored in stack and restored after the interrupts have been handled. After that, handler prints message “Someone's presed a button.”





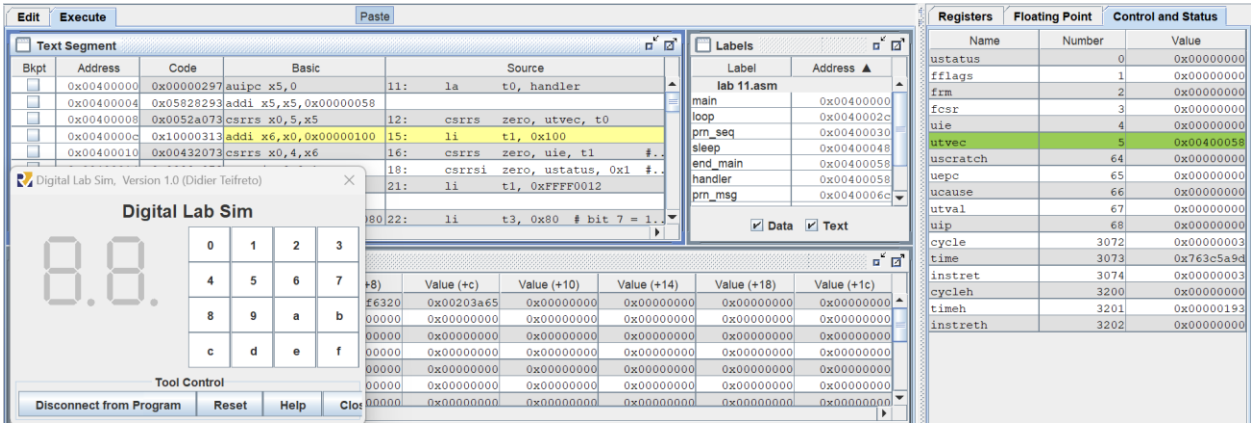


Finally, return to the main program, come back to the instruction which is about to be executed when interrupts occur that its address stored in uepc register. Then, the main program continues to do the loop until interrupts occur again.

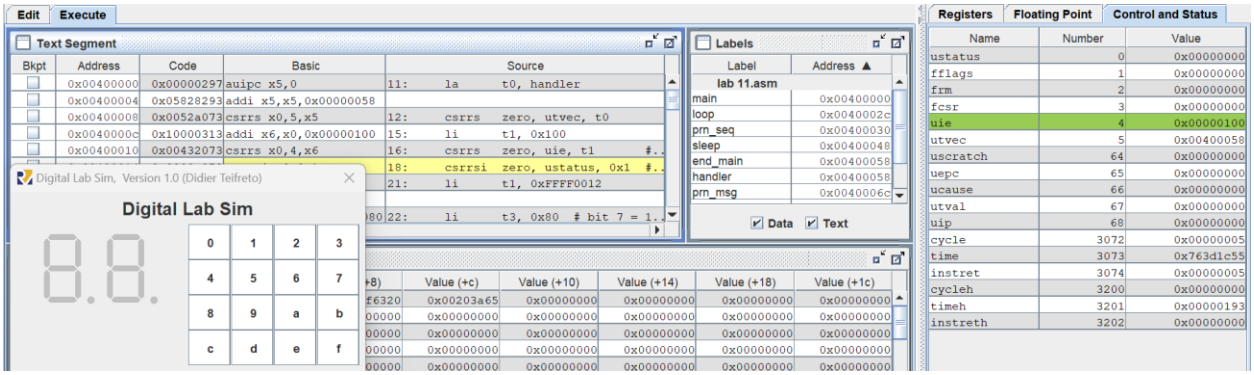


Assignment 3: Create a new project, type in, and build the program of Home Assignment 3. Run the program step by step to understand each line of the source code. Upgrade the source code so that it could detect all 16 key buttons, from 0 to F.

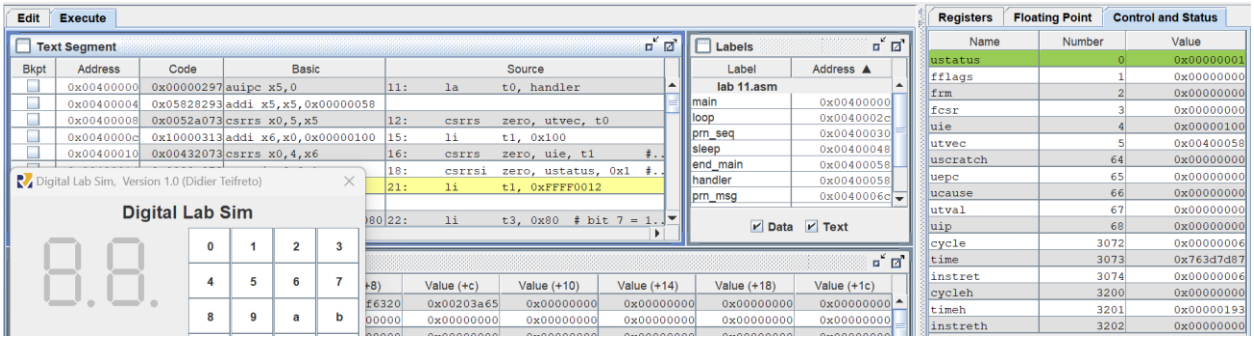
Then, assign this address to utvec



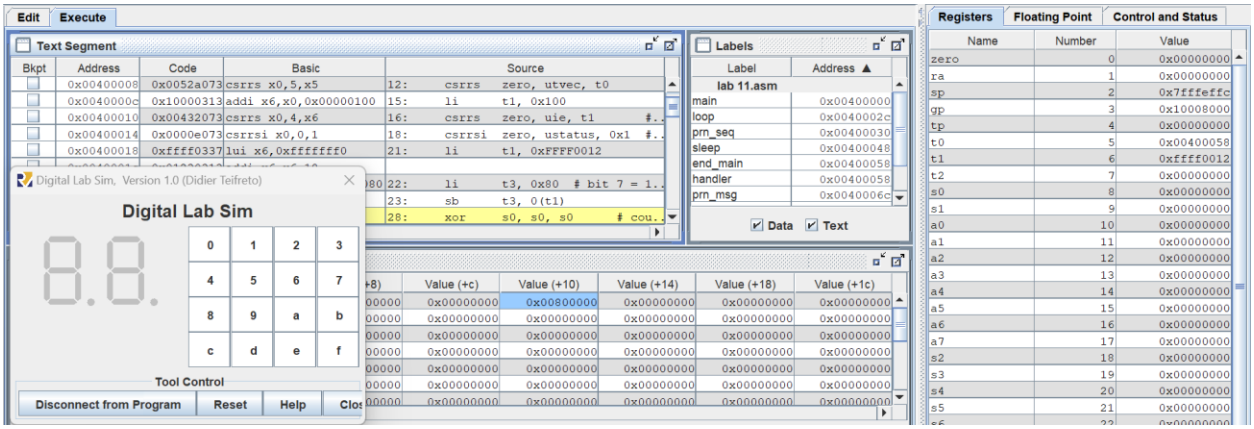
Set the UEIE bit in UIE register (bit 8)



Set the UIE bit (bit 0) in USTATUS register in order to enable interrupts

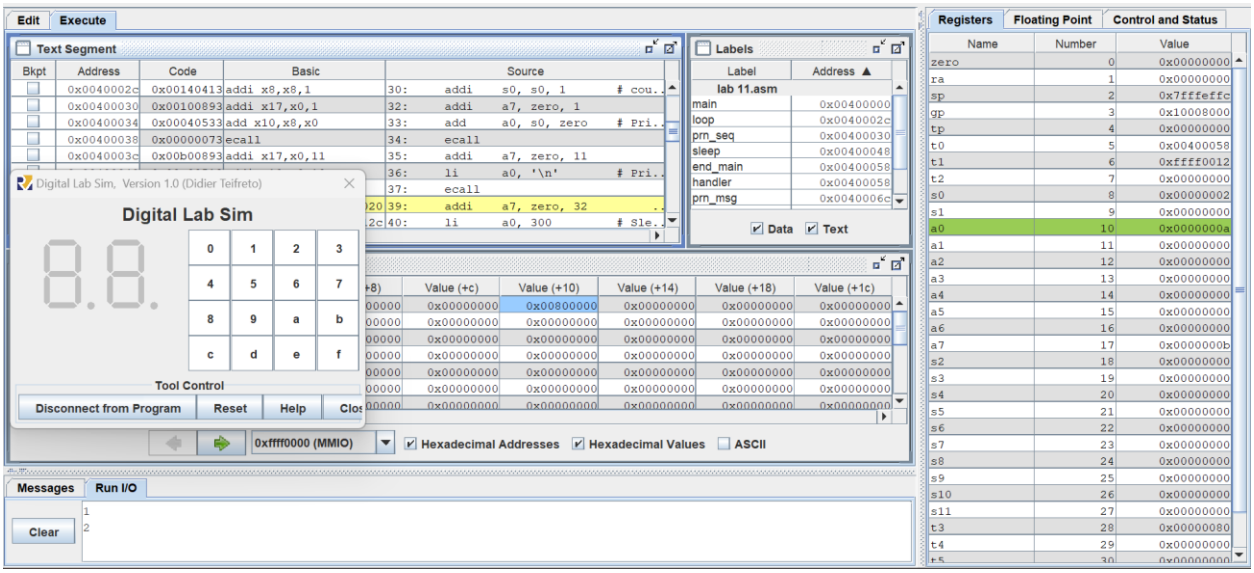


Enable the interrupt of keypad of Digital Lab Sim, set bit 7 to value of 1

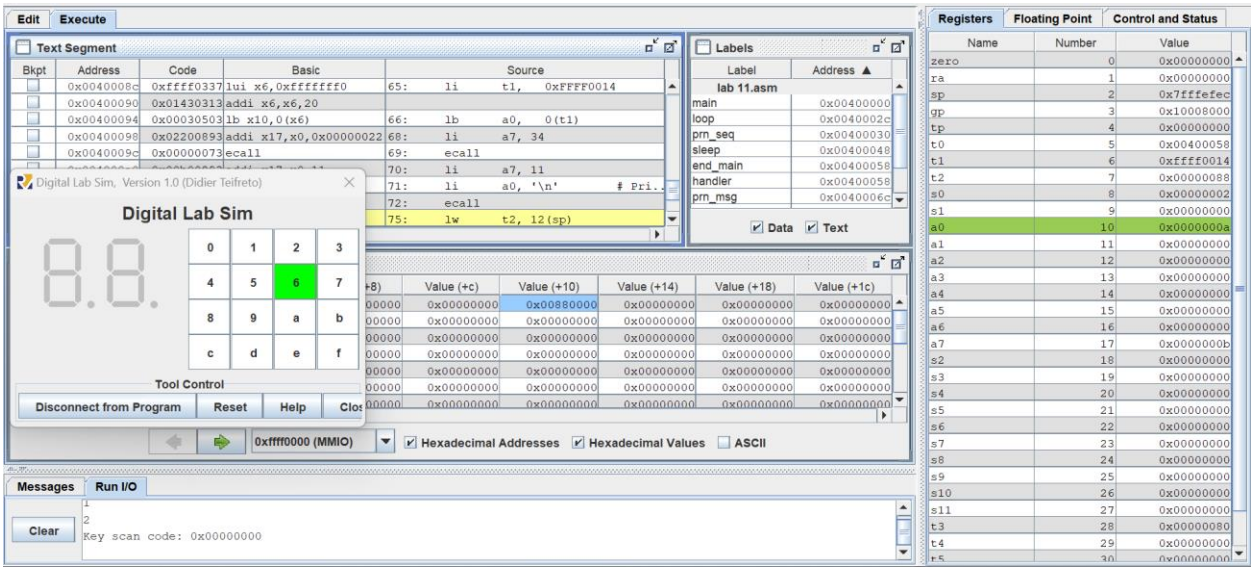


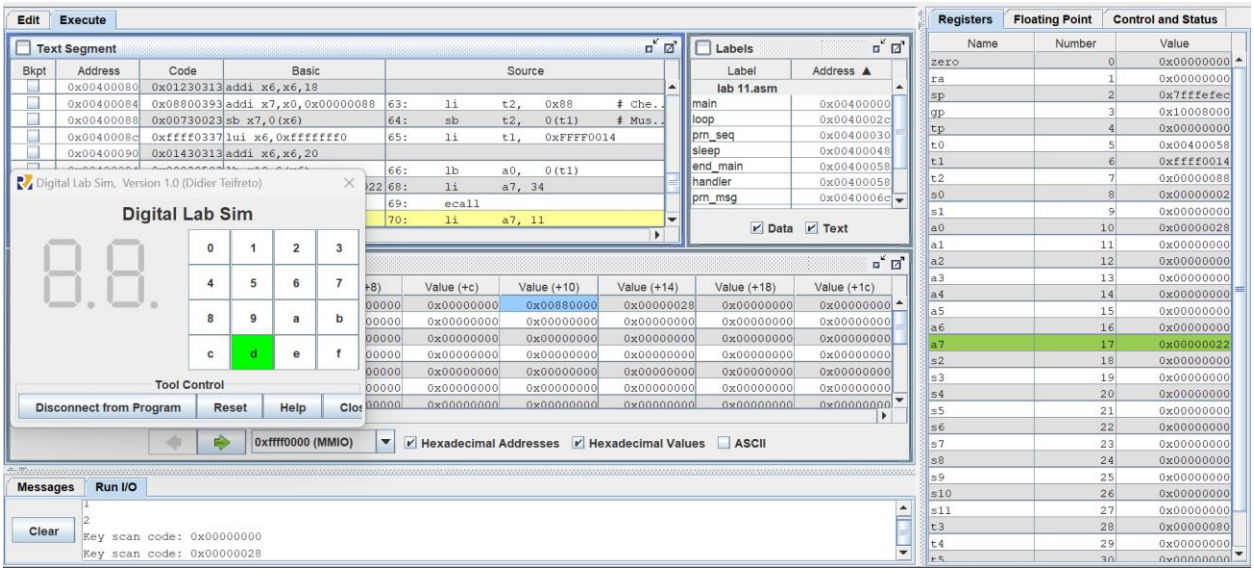
At this time, we have already finished all of preparation and just wait for interrupts occurring.

The main program will have executed the loop and printed sequence of number starting at 1 until interrupts occur.



The main program stops temporarily in order to handle the interrupts. Before handling, we store the current context in stack and restore it after interrupts have already handled. In this case, the interrupts are pressing button. If user presses any buttons in row 4, handler prints the number key of that button. If user presses other buttons which are not in row4, handler prints value of 0x00000000.





After handling the interrupts, return to the main program, continue to do the loop and wait for the next interrupts.

The updated source code is as below:

Edit | Execute

lab 11.asm

```
1  .eqv IN_ADDRESS_HEXA_KEYBOARD       0xFFFF0012
2  .eqv OUT_ADDRESS_HEXA_KEYBOARD      0xFFFF0014
3  .data
4      message: .asciz "Key scan code: "
5  # ---------------------------------------------------------------
6  # MAIN Procedure
7  # ---------------------------------------------------------------
8  .text
9  main:
10     # Load the interrupt service routine address to the UTVEC register
11     la      t0, handler
12     csrrs   zero, utvec, t0
13
14     # Set the UEIE (User External Interrupt Enable) bit in UIE register
15     li      t1, 0x100
16     csrrs   zero, uie, t1       # uie - ueie bit (bit 8)
17     # Set the UIE (User Interrupt Enable) bit in USTATUS register
18     csrrsi  zero, ustatus, 0x1  # ustatus - enable uie (bit 0)
19
20     # Enable the interrupt of keypad of Digital Lab Sim
21     li      t1, IN_ADDRESS_HEXA_KEYBOARD
22     li      t3, 0x80  # bit 7 = 1 to enable interrupt
```

Edit | Execute

lab 11.asm

```
21     li      t1, IN_ADDRESS_HEXA_KEYBOARD
22     li      t3, 0x80  # bit 7 = 1 to enable interrupt
23     sb      t3, 0(t1)
24
25     # ---------------------------------------------------------
26     # Loop to print a sequence numbers
27     # ---------------------------------------------------------
28     xor     s0, s0, s0      # count = s0 = 0
29 loop:
30     addi    s0, s0, 1       # count = count + 1
31 prn_seq:
32     addi    a7, zero, 1
33     add     a0, s0, zero    # Print auto sequence number
34     ecall
35     addi    a7, zero, 11
36     li      a0, '\n'        # Print EOL
37     ecall
38 sleep:
39     addi    a7, zero, 32
40     li      a0, 300         # Sleep 300 ms
41     ecall
42     j       loop
```

Line: 62 Column: 41 ☑ Show Line Numbers

Edit Execute

lab 11.asm

```
42      j       loop
43  end_main:
44
45  # ---------------------------------------------------------------
46  # Interrupt service routine
47  # ---------------------------------------------------------------
48  handler:
49      # Saves the context
50      addi    sp, sp, -16
51      sw      a0, 0(sp)
52      sw      a7, 4(sp)
53      sw      t1, 8(sp)
54      sw      t2, 12(sp)
55
56      # Handles the interrupt
57  prn_msg:
58      addi    a7, zero,  4
59      la      a0, message
60      ecall
61  get_key_code:
62          li      t1,   IN_ADDRESS_HEXA_KEYBOARD
63          li  t2, 0x81
```

Line: 62 Column: 41 Show Line Numbers

Edit Execute

lab 11.asm

```
63          li  t2, 0x81
64          sb  t2, 0(t1)       # must reassign expected row
65          li      t1,   OUT_ADDRESS_HEXA_KEYBOARD
66          lb  a0, 0(t1)        # read scan code of key button
67          bnez a0, prn_key_code
68
69          li      t1,   IN_ADDRESS_HEXA_KEYBOARD
70          li t2, 0x82
71          sb t2, 0(t1)
72          li      t1,   OUT_ADDRESS_HEXA_KEYBOARD
73          lb a0, 0(t1)
74          bnez a0, prn_key_code
75
76          li      t1,   IN_ADDRESS_HEXA_KEYBOARD
77          li t2, 0x84
78          sb t2, 0(t1)
79          li      t1,   OUT_ADDRESS_HEXA_KEYBOARD
80          lb a0, 0(t1)
81          bnez a0, prn_key_code
82
83          li      t1,   IN_ADDRESS_HEXA_KEYBOARD
84          li t2, 0x88
```

Line: 62 Column: 41 Show Line Numbers

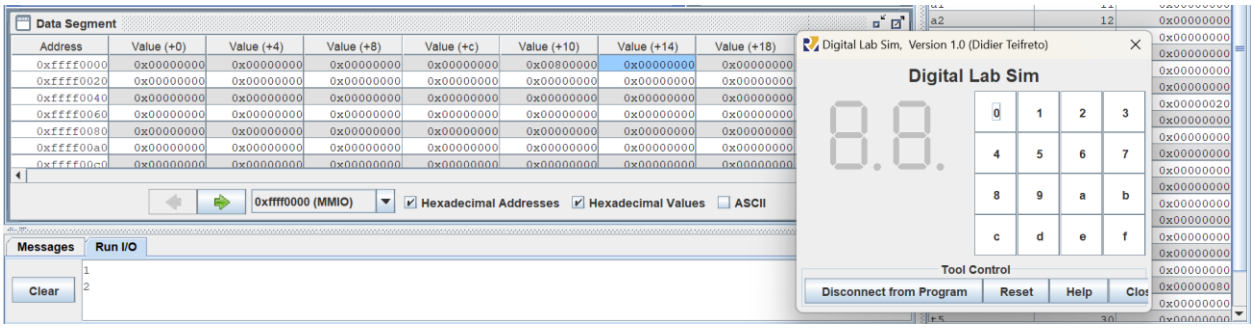
Edit Execute

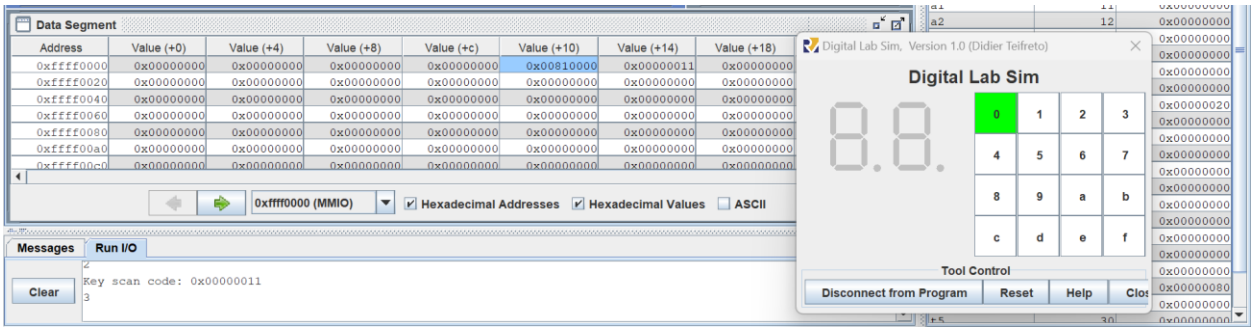
lab 11.asm

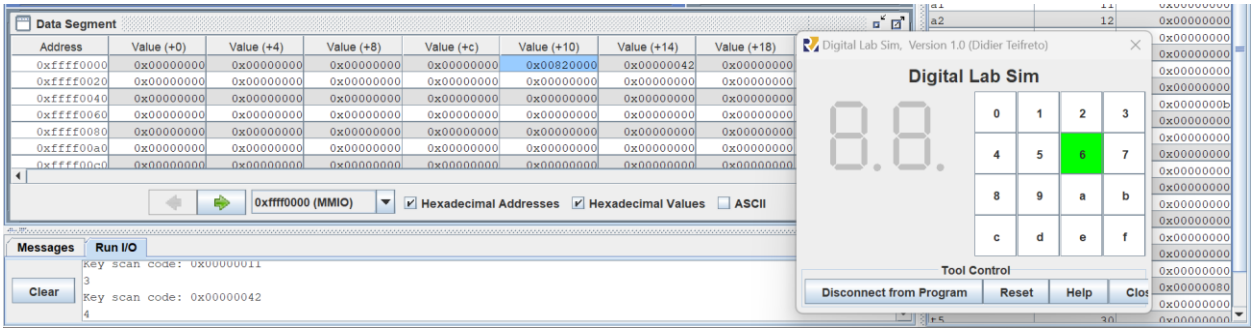
```
84          li t2, 0x88
85          sb t2, 0(t1)
86          li      t1,   OUT_ADDRESS_HEXA_KEYBOARD
87          lb a0, 0(t1)
88          bnez a0, prn_key_code
89      prn_key_code:
90          li      a7, 34
91          ecall
92          li      a7, 11
93          li      a0, '\n'        # Print EOL
94          ecall
95
96          # Restores the context
97          lw      t2, 12(sp)
98          lw      t1, 8(sp)
99          lw      a7, 4(sp)
100         lw      a0, 0(sp)
101         addi    sp, sp, 16
102
103         # Back to the main procedure
104         uret
```

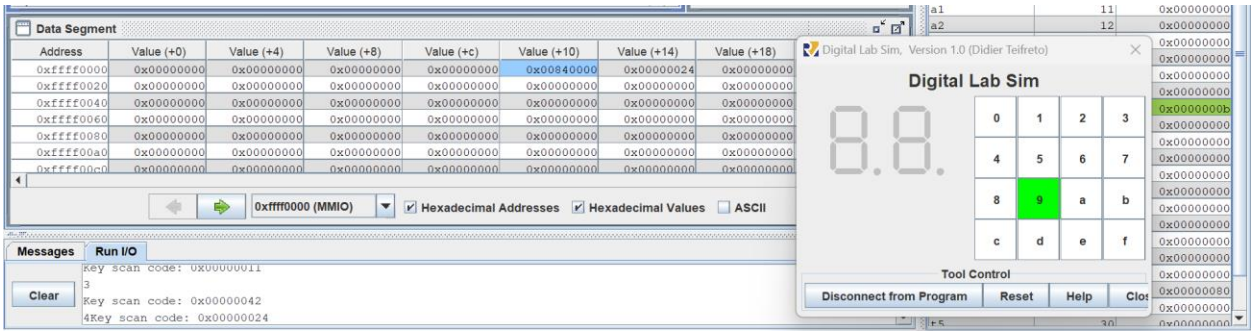
Line: 62 Column: 41 Show Line Numbers

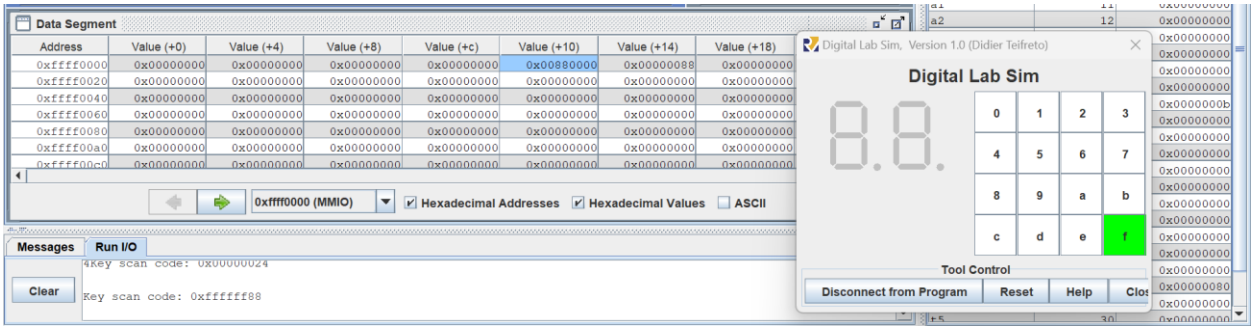
The result is:








Data Segment
Address
Value (+0)
Value (+4)
Value (+8)
Value (+c)
Value (+10)
Value (+14)
Value (+18)
0xffff0000
0xffff0020
0xffff0040
0xffff0060
0xffff0080
0xffff00a0
0xffff00c0
0x00000000
0x00840000
0x00000024
0xffff0000 (MMIO)
Hexadecimal Addresses
Hexadecimal Values
ASCII
Messages
Run I/O
Clear
Key scan code: 0x00000011
3
Key scan code: 0x00000042
4Key scan code: 0x00000024
Digital Lab Sim, Version 1.0 (Didier Teifreto)
Digital Lab Sim
8.8.
0
1
2
3
4
5
6
7
8
9
a
b
c
d
e
f
Tool Control
Disconnect from Program
Reset
Help
a1
a2
11
12


Data Segment
Address
Value (+0)
Value (+4)
Value (+8)
Value (+c)
Value (+10)
Value (+14)
Value (+18)
0xffff0000
0xffff0020
0xffff0040
0xffff0060
0xffff0080
0xffff00a0
0xffff00c0
0x00000000
0x00880000
0x00000088
0xffff0000 (MMIO)
Hexadecimal Addresses
Hexadecimal Values
ASCII
Messages
Run I/O
Clear
4Key scan code: 0x00000024
Key scan code: 0xffffff88
Digital Lab Sim, Version 1.0 (Didier Teifreto)
Digital Lab Sim
8.8.
0
1
2
3
4
5
6
7
8
9
a
b
c
d
e
f
Tool Control
Disconnect from Program
Reset
Help